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Simultaneous placement and sizing of DGs and shunt capacitors in distribution systems by using IMDE algorithm

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ABSTRACT

This paper presents a new optimization algorithm, named intersect mutation differential evolution (IMDE) to optimally locate and to determine the size of DGs and capacitors in distribution networks simultaneously. The objective function is taken to minimize the power loss and loss expenses providing that the bus voltage and line current remain in their limits. Simulation results on IEEE 33-bus and 69-bus standard distribution systems show the efficiency and the superior performance of the proposed method when it is compared with other algorithms.

Introduction

The increasing number of consumers and how to supply the loads are the most important challenges in the power system. Since the cost of construction or upgrading transmission lines and distribution networks is very high, the proper utilization of the low cost DGs has been a solution to eliminate or to delay such investments [1].

Moreover, among different sections of the power system, distribution network has the largest portion of the power loss because of its low level voltage with having a high current [1]. In this regard, it has been shown that one of the most cost-effective and an economical solution to solve this problem is to use DG resources [2]. In this regard, the optimal operation and planning of distribution networks, considering power system uncertainties, especially in the modern smart distribution networks are also very important. Refs. [3–6] highlight the importance of energy storage in combination with distributed generation for these purposes. More information about the application of DGs in implementing smart distribution network functions such as self-healing ability can be found in [7].

In addition to economic concerns, the power quality, reliability, energy saving and stability will be greatly improved by using DGs if they are installed in appropriate places [2]. Thus, determining the capacities and locations of DGs have been the subjects of several papers in which different optimization techniques such as genetic algorithms, continuous power flow, ant colony, particle swarm optimization have been used [8–11]. Analytical methods for finding the optimal size of different types of DGs are also suggested in [12]. In [13] an analytical method and in [14–17] numerical techniques are applied to find the optimal locations and sizes of multiple DGs. A fuzzy GA is employed to solve a weighted multi-objective optimal DG placement model [18–19].

Furthermore, it is very common to use reactive power sources such as parallel capacitors to improve the voltage profile as well as reducing the power losses in the lines. Refs. [20–23] determine the locations and sizes of shunt capacitors with different goals and algorithms.

Considering the advantages of using both DGs and capacitors in distribution networks many researchers have recently proposed different techniques to simultaneously determine the locations and sizes of both to improve the voltage stabilization, system capacity release, energy loss minimization and reliability enhancement. Ref. [24] uses the PSO algorithm to find the optimal location and size of shunt capacitor and DG in 12, 30, 33 and 69-bus IEEE standard networks in order to minimize losses. The IEEE 33-bus network is employed as a test system in [25] to show the advantage of using an improved genetic algorithm for locating DG and capacitor. The same purpose was followed in [26] by using BFOA in the 33-bus network, and results are compared for three different cases of when; 1- only DG, 2- both DG and capacitor, and 3- none of them, are used in the test system. In [27] the problem of locating both DG and capacitor is solved by using BPSO algorithm, where in addition to the main objectives of loss reduction and voltage

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Nomenclature

Symbol	Description
AP_{i+1}	amplitude of injected active power at bus $i+1$
CR	crossover parameter
CT_1	active power base load electricity prices
CT_2	reactive power base load electricity prices
D	number of variables
F	mutation parameter
$F(\cdot)$	fitness function
f	cost of the loss in the period of T year
G	number of generations
I_{ij}	current flowing from bus i to bus j
NP	number of population
n_j	a randomly generated dimension
P	population
P_{DG}	active power of each DG
P_i	net active power of bus i
P_L	active power loss in the line
P_{Li}	active load power at bus i
P_{loss}	system active loss after DG and capacitor installation
P_{loss0}	system active loss before DG and capacitor installation
Q_C	reactive power of capacitor source
Q_i	net reactive power of bus i
Q_L	reactive power loss in the line
Q_{li}	reactive load power at bus i
Q_{loss}	system reactive loss after DG and capacitor installation
Q_{loss0}	system reactive loss before DG and capacitor installation
$r(j)$	a random number between [0,1]
$R_{i,i+1}$	resistance of the line between buses i and $i+1$
RP_{i+1}	amplitude of injected reactive power at bus $i+1$
T	useful life of the equipment
TP_{loss}	total active loss
TQ_{loss}	and total reactive loss
U	trial vector
$u_{i,j}$	jth member of ith trial vector
$u^j_{i,G+1}$	jth member of ith trial vector in the previous generation
V	mutant vector
V_i	voltage of bus i
$v_{i,j}$	jth member of ith mutant vector
$v^j_{i,G+1}$	jth member of ith mutant vector in the previous generation
X_{br}	individual chosen from the better part
$X_i^{(G)}$	target vector in the previous generation
$Xi^{(G+1)}$	ith vector in the next generation
$X_{i,i+1}$	reactance of the line between buses i and $i+1$
$x_{i,j}$	jth member of ith target vector
$x^j_{i,G}$	jth member of ith target vector in the previous generation
X_{wr}	individual chosen from the worse part
$x_{i,j}$	jth member of ith target vector
α	conversion ratio of operating expense
β	inflation rate
μ	annual interest rate
μ_P	active power coefficient
μ_q	reactive power coefficient

List of abbreviations

ABC	Artificial Bee Colony
BFOA	Bacterial Foraging Optimization Algorithm
BGSA	Binary Gravitational Search Algorithm
BPSO	Binary Particle Swarm Optimization
BSO	Bee Swarm Optimization
DE	Differential Evolution
DG	Distributed Generation
DPSO	Discrete Particle Swarm Optimization
FGA	Fuzzy Genetic Algorithm
GA	Genetic Algorithm
ICA	Imperialist Competitive Algorithm
IMDE	Intersect Mutation Differential Evolution Algorithm
IPSO	Improved Particle Swarm Optimization
PSO	Particle Swarm Optimization
TLBO	Teaching–Learning-Based Optimization

improvement, the network reliability indices are used. In [28] both artificial bee colony and artificial immune system algorithms are combined to locate and to determine the size of capacitors and DGs in distribution networks. The proposed method was tested on IEEE 33-bus test system for several cases. The simulation results show that the proposed approach provides better power loss reduction and voltage profile enhancement when compared with different methods. DGs and capacitors are optimally located and sized in [29] by using DPSO algorithm. Ref. [30] employs TLBO technique to maximize the ratio of the profit to cost when both capacitor and DG are used. Other algorithms such as BGSA [31], simple genetic algorithm [32,33], genetic and ICA techniques [34] have been also used in this field.

This paper presents a new algorithm, named IMDE [35] to optimally locate DGs and shunt capacitors as well as determining their sizes in radial distribution networks. This algorithm not only has a higher convergence speed, but also gives a better performance compared to earlier works in this field. The results clearly show the highest level of loss reduction as well as keeping the voltages of buses within their limits.

Differential evolutionary algorithm

Differential evolution (DE) is one of the meta-heuristic algorithms, which is widely used because of its nature and special features, especially for having a fast convergence. DE differs from other evolutionary algorithms in the mutation and recombination phases. It uses weighted differences between solution vectors to change the population, whereas in other stochastic techniques such as GA and expert systems, perturbation occurs in accordance with a random quantity. This algorithm also provides a simple and efficient way to calculate the global optimal solutions in both continuous and discrete spaces [36].

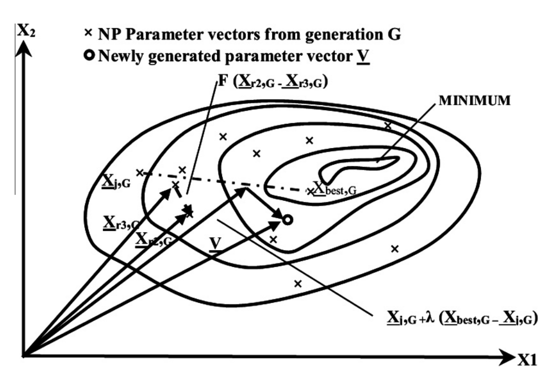

Fig. 1. Overview of behavior of the algorithm [36].